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(56) Documents cited
GB 2155699 A GB 2155696 A

(58) Field of search
UK CL (Edition K) H1Q QEE QEX
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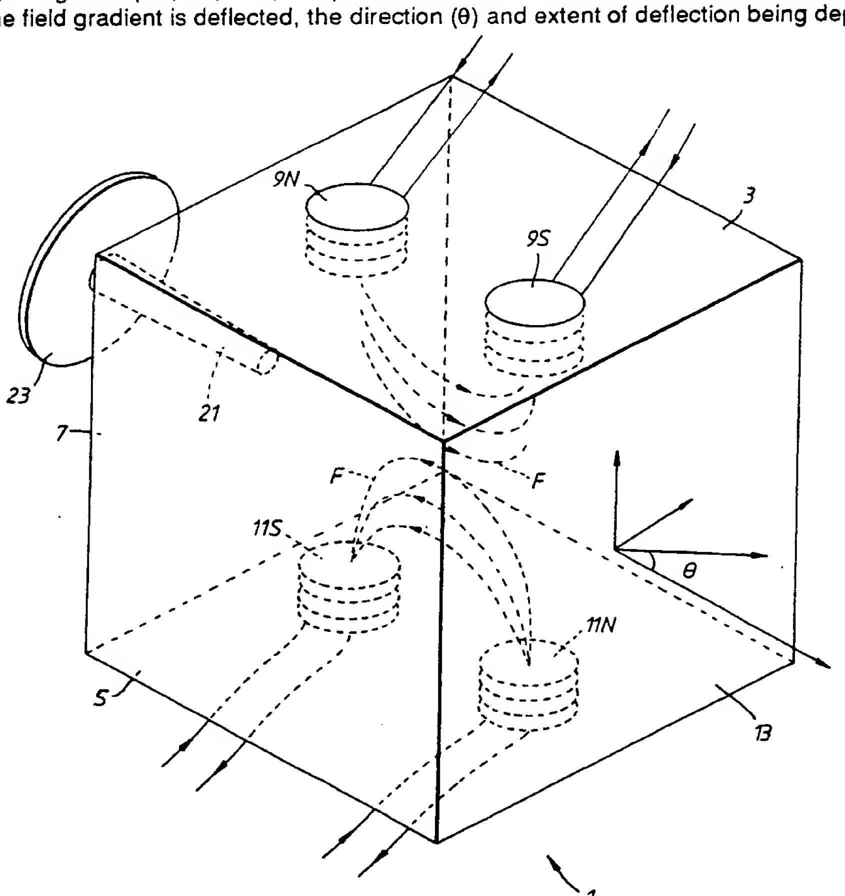
(54) **Microwave beam-steering devices**

(57) A microwave beam-steering device comprises a block (1) of ferromagnetic material across which a magnetic field gradient is applied, using coils (9N, 9S, 11N, 11S) within the block. Microwave radiation incident on the block in a direction perpendicular to the field gradient is deflected, the direction (θ) and extent of deflection being dependent on the magnetic field.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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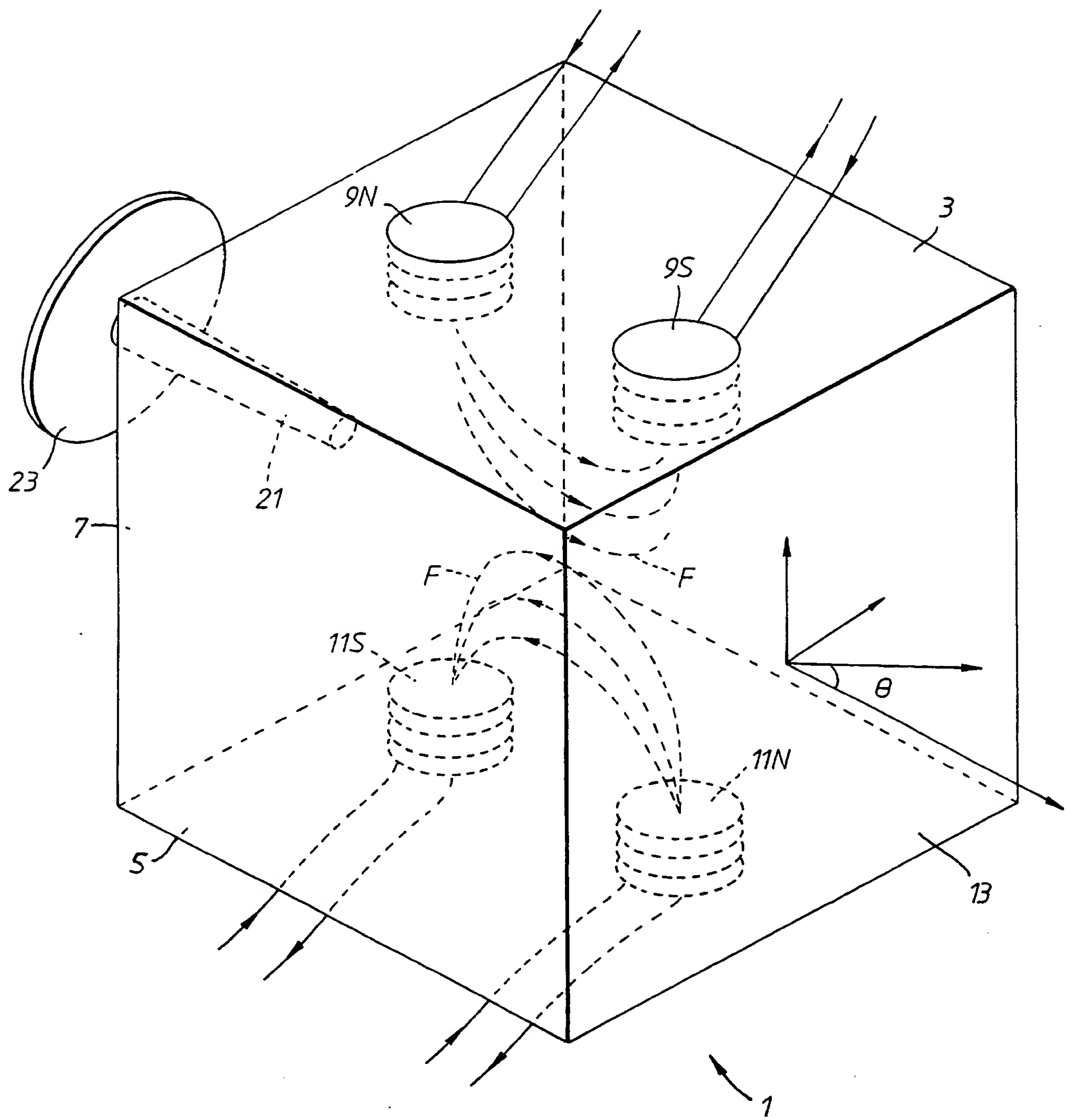
9N
3
9S
23
21
7
F
F
11S
θ
11N
5
13
1

Microwave Devices

This invention relates to microwave devices.

More particularly the invention relates to microwave devices adapted to be positioned in the path of a beam of electromagnetic microwave energy propagating in free space for controlling the direction of the beam leaving the device.

In a known microwave beam controlling device, the microwave beam passes through a rectangular block of dielectric material formed by two wedge-shaped members, one of ferrite and one of non-ferrite material with their sloping faces in juxtaposition. An external magnetic field is applied to the block in a direction perpendicular to the direction of propagation of the microwave beam. Since the permeability of the ferrite material varies with the magnetic field applied, a beam travelling through the ferrite will travel more quickly when a magnetic field is applied. If a microwave beam is directed through the block so as to travel in turn through the ferrite and non-ferrite material, opposite edges of the beam will travel through different lengths of ferrite material causing a differential phase shift. Thus the beam is deflected since the phase at one edge lags that at the other edge.

Devices of this kind are difficult to construct and prone to errors due to beam reflection at the junction between the ferrite, and non-ferrite wedge-shaped members. They produce beam deflection in one plane only; two devices in series would be required to produce conical steering. Only an external solenoid can be used to control such devices.

According to the present invention there is provided a device for controlling the direction of a beam of microwave radiation comprising: a body of dielectric material, having a permeability which varies with an applied magnetic field, and means for applying a gradient to said said magnetic field, said gradient being in a direction perpendicular to the direction of propagation of a beam of microwave radiation incident on said body of dielectric material.

Preferably the magnetic field is substantially parallel to the direction of propagation of the beam through a body. The means for applying a gradient to the magnetic field may comprise sources of magnetic flux positioned on opposite sides of the axis defined by the direction of propagation of said beam, said sources being adapted to produce magnetic fields in opposite directions.

It is preferred that the magnetic field be in opposite directions on opposite sides of said beam. Thus the resultant flux along the direction of propagation of the beam will be zero.

Preferably the magnetic field has two gradients in directions perpendicular to one another. This enables the direction of the beam to be controlled in azimuth as well as in elevation.

Conical beam steering using this device may best be achieved by embedding pairs of coils in proximity to all four faces of the dielectric block through which the incident beam does not pass.

The gradient or gradients are preferably substantially linear.

Ferrite material has proved particularly suitable for the dielectric material of a device according to the invention since it combines high permeability with low conductivity and thus has low losses. Due to this low conductivity, ferrites are easily penetrated by microwave fields.

One device in accordance with the invention will now be described by way of example with reference to the accompanying drawing which is a diagram illustrating the device.

Referring to the drawing, the device comprises a square block 1 of ferrite material having pairs of identical circular coils 9N, 9S and 11N, 11S embedded in recesses provided in opposite faces 3 and 5 of the block 1. Each coil is positioned with its axis normal to the faces 3, 5 with the axes of the coils 9N and 9S in parallel spaced relationship and the coils 11S and 11N respectively coaxial with the coils 9N and 9S.

In use of the device the coils 9S, 9N, 11S, 11N are energised by the same current source so that the magnetic field produced by the two coils 9N and 9S in the central region of the block is in a direction generally normal to faces 7 and 13 of the block and in the opposite direction to the magnetic field produced in the central region of the block 1 by the coils 11N and 11S, as indicated by lines F. As a result the magnetic field produced in the central region of the block 1 when the coils are energised has a gradient in the direction parallel to the axes of the coils, i.e. to the faces 7 and 13, with zero magnetic field in a plane parallel to and central between the faces 3 and 5.

When a beam 21 of circularly polarised microwave energy is directed centrally onto the face 7 of the block 1 in a direction normal to the plane of the face 7 by means of a suitable lens arrangement 23 e.g. a dielectric lens, and no current is supplied to the coils, the beam 21 emerges from the block 1 via the face 13 opposite the face 7 in the same direction as the beam 21 is incident on the face 7. However, when a current is supplied to the coils the beam 21 emerges from the block 1 in a direction at an angle θ to the

normal to the face 13, where θ lies in a plane parallel to the resultant field and increases as the current applied to the coils increases.

The deflection of the beam arises as a result of differential phase shift across the beam in the direction of the magnetic field gradient on the magnetic field directed parallel to the direction of the propagation of the beam. This differential phase shift is caused by changes in the permeability of the ferrite along the direction parallel to the axes of the coils. Between the central plane and face 3 the magnetic field is in one direction, whilst it is in the opposite direction between the central plane and face 5. Since the permeability of the ferrite depends on the direction and magnitude of the magnetic field, the phase at the top of the beam will lag that at the bottom of the beam and the beam will be deflected upwards. To deflect the beam downwards, the direction of current flow in the coils is reversed to switch the direction of the magnetic fields.

The degree of deflection is controlled by varying the curent supplied to coils to alter the magnitude of the magnetic fields.

In one particular embodiment of the device shown in the figure, the ferrite block has dimensions of 30 mm. The surfaces of the block are drilled to provide circular recesses into which coils of diameter 0.8 cm, each having 4 turns of 0.6mm diameter wire, may be inserted. To complete the magnetic circuit for the flux produced within the block, each recessed face of the block is provided with a cover (not shown) of the same ferrite material as the block which is approximately 5mm thick. The effect of these covers is to reduce flux leakage to the atmosphere. The ferrite material is a magnesium ferrite material of type TT1-3,000 sold by Trans-Tech Inc. which has a dielectric constant of 12.5 and a saturation magnetisation value of 0.3 Tesla.

A beam of circular cross-section of diameter 20 mms and frequency 95 GHz is deflected by the device through 8° when a current of 1.6 A passes through all the coils.

The device is suitably matched to free space at its input and output ends by means of a coating (not shown) of dielectric material on faces 7 and 13.

To establish the required magnetic field gradient in the block material, the windings may be energised continuously.

However, if the material used is a ferrite which has a 'square' B-H characteristic, pulses may be applied to the windings to latch the remanent magnetisation in the ferrite to desired points on the B-H characteristic in a manner well known with other ferrite devices. No demagnetizing fields are present and no holding current is required.

It will be appreciated that the dielectric material chosen should exhibit low loss at the microwave frequencies concerned, satisfactory power handling capability, good temperature stability and high saturation magnetisation value, the latter so that the largest possible maximum beam deflection is obtained.

One particular application envisaged for a device in accordance with the invention is in a rapid-scanning antenna e.g. in radar equipment, the device having the advantage over conventional such antennae that no mechanical motion is involved.

In general the device may find application in any equipment wherein quasi-optical transmission of radio waves between components of the system is employed.

Whilst the coils which produce the magnetic field within the block of dielectric material are shown as having a circular cross-section, they may alternatively have an elliptical cross-section to produce a more uniform magnetic field in proximity to the sides of the block.

To reduce edge effects the edges and corners of the block may be bevelled.

CLAIMS

1. A device adapted to be positioned in the path of a beam of electromagnetic microwave energy propagating in free space for controlling the direction of the beam leaving the device comprising: a body of dielectric material having a permeability which varies with an applied magnetic field, means for directing a beam of microwave radiation through the body, and means for applying to said body a magnetic field, having a gradient in a direction perpendicular to the direction of propagation of said beam.

2. A device as claimed in Claim 1 wherein said magnetic field is substantially parallel to the direction of propagation of the beam through the body.

3. A device as claimed in Claim 1 or Claim 2 wherein the magnetic field is in opposite directions on opposite sides of the axis defined by the direction of propagation of said beam.

4. A device as claimed in Claim 2 or 3 wherein said means comprises sources of magnetic flux positioned on opposite sides of the axis defined by the direction of propagation of said beam, said sources being adapted to produce magnetic fields in opposite directions.

5. A device as claimed in Claim 4 wherein each said source comprises a pair of coils.

6. A device as claimed in any preceding claim wherein said magnetic field has two gradients in directions perpendicular to one another and to the direction of propagation of said beam.

7. A device as claimed in any preceding claim wherein said dielectric material is a ferrite.

8. A device as claimed in any preceding claim wherein said gradient or gradients are substantially linear.

9. A device adapted to be positioned in the path of a beam of electromagnetic microwave energy propagating in free space for controlling the direction of the beam leaving the device substantially as hereinbefore described with reference to the accompanying drawing.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number 9106106.9

Relevant Technical fields

(i) UK Cl (Edition K) H1Q (QEE, QEX)

(ii) Int Cl (Edition 5) Selected US specifications in IPC Sub-Class H01Q

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner Miss J E Evans

Date of Search 20.8.91

Documents considered relevant following a search in respect of claims 1 to 9

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB-2155699 A (United Technologies) whole document	1 at least
A	GB-2155696 A (United Technologies) whole document	1 at least

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

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